AN INVESTIGATION OF USER GENERATED COCKPIT DISCREPANCIES IN NAVAL AIRCRAFT

Frederick George Schobert

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN INVESTIGATION
OF
USER GENERATED COCKPIT DISCREPANCIES
IN NAVAL AIRCRAFT

by

Frederick George Schobert, Jr.

September 1976

Thesis Advisors: D. E. Neil
L. E. Waldeisen

Approved for public release; distribution unlimited.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
An Investigation of User Generated Cockpit Discrepancies in Naval Aircraft

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis;
September 1976

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Frederick George Schobert, Jr.

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE
September 1976

13. NUMBER OF PAGES
58

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Critical Incident Technique
Aircrew Station Geometry
Problem Incident Technique
Aircraft Design
Aircraft Safety
Man-machine Interface
Cockpit

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This thesis analyzes problems in current Naval aircraft as reported by fleet aviators attending the U. S. Naval Aviation Safety School. A method is developed which facilitates the collection and processing of the reported information. A collective sample of 286 incidents is stratified into a design discrepancy outline which illuminates 31 specific problem areas. Various recommendations are made concerning concept expansion to a fleet-wide level.

An Investigation
of
User Generated Cockpit Discrepancies
in Naval Aircraft

by

Frederick George Schobert, Jr.
Lieutenant, United States Navy
B.S., United States Naval Academy, 1970

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1976

ABSTRACT

This thesis analyzes problems in current Naval aircraft as reported by fleet aviators attending the U. S. Naval Aviation Safety School. A method is developed which facilitates the collection and processing of the reported information. A collective sample of 286 incidents is stratified into a design discrepancy outline which illuminates 31 specific problem areas. Various recommendations are made concerning concept expansion to a fleet-wide level.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The systematic study of documented aircraft problems experienced by operational personnel in the field receives little allocation of the human factors research being done in the Navy today. This seems surprising when one pauses to reflect that military aerial operations are composed of complex man-machine systems functioning in extremely competitive situations. The environment which pits a competitor versus an opponent (whether an actual physical enemy or simply nature) is likely to contain vicissitudes as unsettling as imaginable. Yet most expect maximum mission performance from the system at all times and place demands upon it accordingly. A necessary condition for such optimum performance is that man, the system's most variable and least predictable component, must be allowed to apply his diverse skills to the situation at hand without distraction. Yet, in the actual evolution of a mission, system elements supporting man can operate below optimum performance at any given time. It is this suboptimum performance which can distract an aviator's attention from a critical task and lead to error and mission performance degradation. Usually these errors are attributed to the human. However this paper adopts an alternative approach, namely considering inadequate aircraft design as a major contributing factor to suboptimum performance. It is well within the realm of the Human Factors discipline to study these errors,

determine causes, develop procedures/methods for alleviation, and finally to communicate the results to the design engineer.

Thus there is a need for a human factors method which can systematically collect, classify, and analyze data specifically chosen to aid the designer in both identifying and solving man-machine interface problems. Meister and Sullivan (1967) concluded that current human factors information supplied in the design stage is entirely "too verbal, too general and non-applicable." In fact, Meister and Farr (1966) reported in an earlier study of the perception designers have of such data:

> "Human Factors problems - which are not usually verbalized as such - are settled largely by the designer's placing himself in the role of the equipment operator. Designers have great difficulty in anticipating operational problems that may result from design parameters and are unable to apply evaluative criteria to completed designs."

More recently Wherry (1975) pointed out that current techniques,

> "... rely heavily on the expertise of the human engineer to provide 'good' estimates for the data required by the various techniques and methods ... if the information input into the technique is unreliable and invalid then the output results will also be unreliable and invalid."

Thus it is clear that a data pipeline is sought which could provide the design engineer with more objective information concerning operational problems than he could generate subjectively himself.

A question that might be asked in a search for such data is, "What parameters significantly influence operator performance in the field?" The present thesis represents one approach to this question, using

responses elicited from the users for obtaining evaluative data on operational systems. It is felt that any form of evaluation in system development should include human considerations as well as engineering.

In the area of Naval aircraft cockpit design this implies that Naval Aviators and Naval Flight Officers (NFO'S) should be canvassed for reports of design discrepancies. It is recognized that reports of design problems submitted by the fleet personnel have been a basis for limited modification in the past. Yet too often the human engineer has been faced with single reports with which he must decide if a discrepancy is an isolated problem or, in fact, truly fleet-wide. The collection and classification of a large number of fleet generated design discrepancies is a necessary step in providing a sound, documented basis for modifying existing equipment and designing new systems.

The type of information volunteered by fleet operators is highly subjective in nature. This led to a search of existing techniques for a procedure to classify and analyze such data. This thesis will demonstrate that the Problem Incident Technique can successfully organize this new information into categories that can aid the Navy in four areas:

1. To improve the quality of decisions in developing new Naval aircraft.

2. To aid the design engineer during periods of retrofit of existing Naval aircraft.

3. To provide better integration of hardware and personnel (the man-machine system) in Naval aircraft.

4. To correct design deficiencies early in development programs of new aircraft.

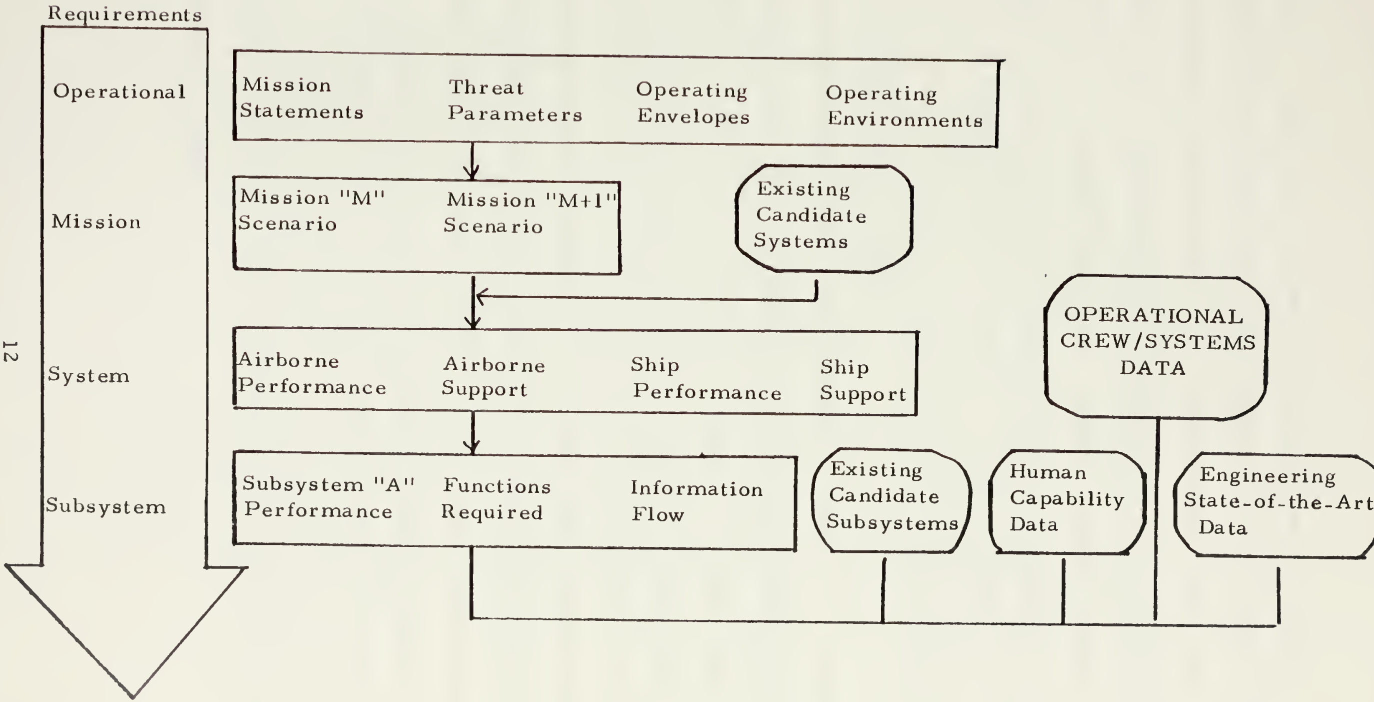
II. BACKGROUND

Since World War II military systems have undergone dramatic periods of retrofit and reorientation during their operational lives. These changes have occurred in response to such variables as changes in the threat, technology alterations involving new or upgraded equipment, or of the deployment of systems in new operational environments. There is little doubt that operators in the field would have benefited during these periods from a comprehensive analysis of their perceived problems.

Such an analysis across various Naval aircraft types could also aid the design engineer faced with evolving a weapon systems development program for new aviation platforms. As an example consider the approach to such a program which has been proposed by Wherry (1975) and is presented in Figure 1.

This program extends from the premise that the only defensible rationale behind the development of future airborne weapon systems is to counter enemy threats as perceived for some given time frame. Thus the first phase consists of defining the operational requirements needed to counter the expected threat parameters. The next phase, mission scenario requirements, discusses how the Navy might perceive the engagement with enemy forces unfolding with time. Third, system capability requirements are described based on the various

FIGURE 1
AIR WEAPON SYSTEMS DEVELOPMENT PROGRAM



scenarios. Finally the subsystem requirements may be defined as "an aggregation of components to accomplish various functions which taken together provide portions of the needed system capabilities" (Wherry, 1975). This may also be viewed as the first of the design stages since it conceptualized how the system might be organized. It is at this level that the value of supplying fleet generated data surfaces. Here it can be blended with (see Figure 1.) human capability and engineering state-of-the-art inputs to provide a real world sieve through which design concepts can be screened.

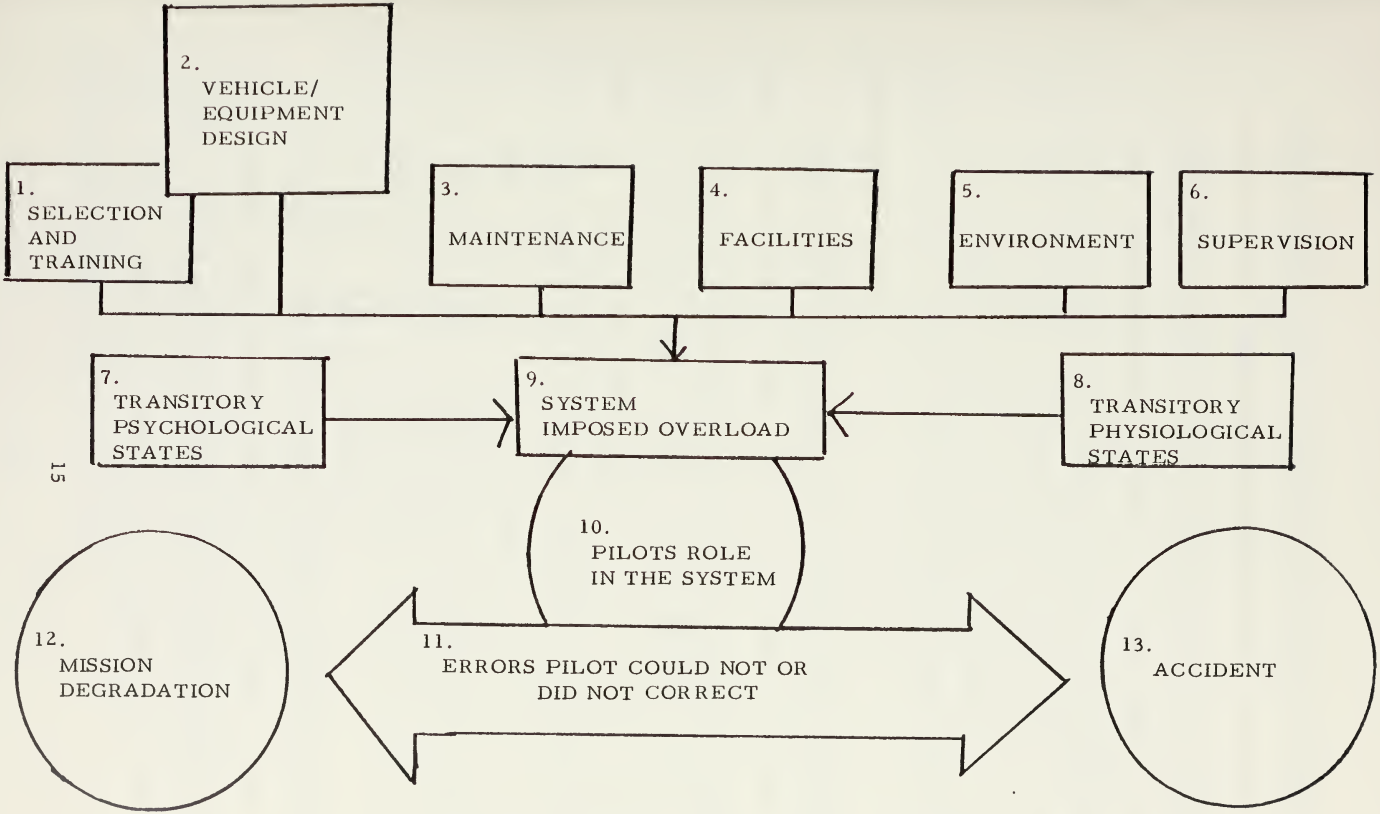
No claim is made that all man-machine problems can be caught by such an approach. But fleet responses can provide a foundation for identifying and diagnosing many otherwise ignored problems which affect mission success (as determined by the humans charged with eliciting performance). It is recognized that most critical and urgent problems do not exist unheeded for long in the normal weapon system design process. However, this technique can potentially identify and document them much earlier - prior to the prototype stage and thus prior to the need for an expensive Engineering Change Proposal. Also it could highlight at the outset factors which are ordinarily not documented in operational field reporting and which when later identified as troublesome downstream in the design process are not deemed worth the expense to change.

III. DESIGN DEFICIENCIES AND PILOT ERROR

The practical goal, the payoff, in developing fleet generated data for identifying critical problem areas involves the reduction of system performance errors. Error may be defined as simply a mistake, a deviation from correct procedure, which results in lost time, damaged equipment, personal injury, or any form of mission degradation.

The Human Factors attitude towards error tends toward the premise that you cannot divorce the man from the system designed for him. Man is a system component - and both the strongest and weakest element in the aviation system at that. He is the strongest because he is the most flexible and adaptable in a given situation. He is the weakest because his performance is unreliable; he cannot perform the same task again and again in an identical manner. Nonetheless, man must be relied upon for effective performance if the system is to accomplish its tasks. To this end the goal of Human Factors is to optimize the design of equipment so that the user's efficiency will be at its peak.

Although this thesis employs a method which concentrates on errors in equipment design rather than human error itself, it is necessary to realize that a causal relationship exists between the two. Ricketson, Kennamore, and Callen (1975) provide a functional definition of pilot (human) error and its causal elements (see Figure 2).



FUNCTIONAL DEFINITION OF PILOT ERROR
FIGURE 2

Items one through eight identify basic environmental elements which influence the aviation system and are potentially error producing. Item two is highlighted in Figure 2 since it represents the focus of this paper, namely vehicle/equipment design. When any of these elements exceeds its normal tolerance level, the pilot must correct for this aberration while continuing to perform his present ongoing tasks. This can result in an overload condition for the aviator which, if it occurs at a critical moment, can induce error. The outcome will be various degrees of performance degradation.

A similar viewpoint was expressed by Meister (1971). He determined that three general causes of error could induce an overload condition. First, error could arise because of an operator's psychological or physiological state - fatigue, lack of capability, lack of motivation. These were called "operator-induced" errors. Second, lack of proper maintenance programs, supervisory practices, facilities, or any other deficiency in total system planning could result in "system-induced" errors. Finally a state conducive to human errors could be induced upon the aviator by design problems in individual equipment; these were termed "design-induced errors.

It is the third category of error, henceforth called design discrepancies, which is highlighted and analyzed by the Problem Incident Technique. These are simply problems with equipment design characteristics which create special difficulty for the operator and which substantially increase the potential for error.

IV. HISTORICAL PERSPECTIVE

The employment of techniques utilizing field type data to analyze system performance problems is not a new development in military aviation. Fitts and Jones (1947a) were early investigators of such methods and analyzed 460 incidents of pilot error involving the operation of aircraft controls. Later Fitts and Jones, (1947b) collected and analyzed 270 pilot error experiences in reading and interpreting aircraft instruments. Their findings concluded that the design of aircraft equipment must take into account the capabilities and limitations of the human operator.

Later applications of the technique involved a flight safety orientation. Korchin and Patterson (1949) collected 497 accounts of "close calls" which were reported by pilots for an evaluation of flight safety media. Vasilas et al (1953) defined these "close calls" as "near accidents" and devised a standard report form for collection of Air Force personnel data. Significantly, they concluded that a group orientation approach (defined in section V.b.) was a highly effective method of data collection for such a study. Ricketson et al (1973) surveyed accident investigation reports for U. S. Army aviation over a fifteen year period. They developed an experimental human error reporting form in the course of their study and concluded that the resultant data held promise for providing a clearer identification of mishap-causing system elements.

Rabideau and Ritchie (1968) employed open-ended questioning of Air Force personnel in interview situations for a study of human engineering problems incurred during tactical air operations in Southeast Asia. A classification of problem commonalities and causative factors resulted in more than two dozen problem areas. Atkins (1969) attempted to collect data inputs for developing new and revised criteria of Air Crew Station Geometry for application in U.S.A.F. aircraft. The research team studied a broad range of sources including accident data, unsatisfactory reports, and aircraft inspections. They concluded that the most fruitful efforts were associated with aircrew generated data.

It is noteworthy that each of the preceding reports cited anonymity as a crucial requirement for any data collection format. Shapiro et al (1960) modified this when applying subjective techniques in a missile system test context. They placed the interviewee in the posture of being an anonymous third person; thus he was allowed to report errors he had observed others commit. This depersonalization mollified the feelings of respondents that their "admission" of performance errors might somehow be used against them.

In spite of their differences, all of the preceding studies illuminated mission event incidents in which the performance of any system or subsystem was such as to cause some form of mission degradation. The remaining sections of this paper will study a technique which utilizes design discrepancies for the illuminating incidents. Although the objectives of the above works are somewhat different from the present thesis,

nonetheless they provided approaches and procedures which proved of value in promoting the present analysis.

V. PROBLEM INCIDENT REPORTING TECHNIQUE

Van Cott and Kincaid (1972) state that the essence of a human engineering test consists of answering such questions as the following:

"1. Can the operator use the equipment?
2. If so how well?
3. If not what is considered the problem by the operators who are part of the system?"

The basic premise put forth is that equipment can not be tested and evaluated independent of the human beings who will work with it.

The Problem Incident Reporting Technique (Meister and Rabideau, 1965) is aimed specifically at answering the third question. It is closely related to, but not precisely the same as, the Critical Incident Technique proposed by Flanagan (1962).

The Critical Incident Technique as originally postulated consisted of a procedure for analyzing and classifying what are, in essence, anecdotally reported observations. For the most part Flanagan used these for developing job requirements; thus he classified examples of both effective and ineffective behavior. However, the main concern of this paper is to collect problem incidents (which might be construed as "negative" incidents as opposed to "positive" items) for the purpose of alleviating poor design performance. It is these problem incidents which illuminate operator difficulties and presage breakdowns in mission effectiveness; thus, they can be used to identify the types of design behavior which should be carefully evaluated by the human engineer.

Meister (1965) proposed that problem incidents, when used in conjunction with the Problem Incident Reporting Technique, could be of value in indicating the following:

1. Events which under adverse conditions could jeopardize safety of personnel and/or damage equipment;

2. Human errors in operating equipment;

3. Operator difficulties in performing mission tasks;

4. Inadequate system parameters (i. e. job environment, equipment design) that affect system performance.

The remainder of this paper is an application of this technique to the area of Naval aircraft design.

A. DATA SOURCE

Daniels (1976) suggested that the U. S. Naval Aviation Safety School at the Naval Postgraduate School, Monterey, California, provided a convenient data source for questions of aviation design. Classes of twenty to forty Naval Aviators/Naval Flight Officers convene at six week intervals. Each section is composed of a professional and recently proficient group of fleet aviators that mirrors the spectrum of Naval aircraft types and communities. It thus provides an inexpensive data source that suffices for the initial problem conceptualization.

It is recognized that such data will be biased somewhat since safety school entrants in general tend to be more proficient than the fleet norm; they have perhaps mastered a design problem that could hinder the "nugget" aviator. Yet this paper is concerned with establishing

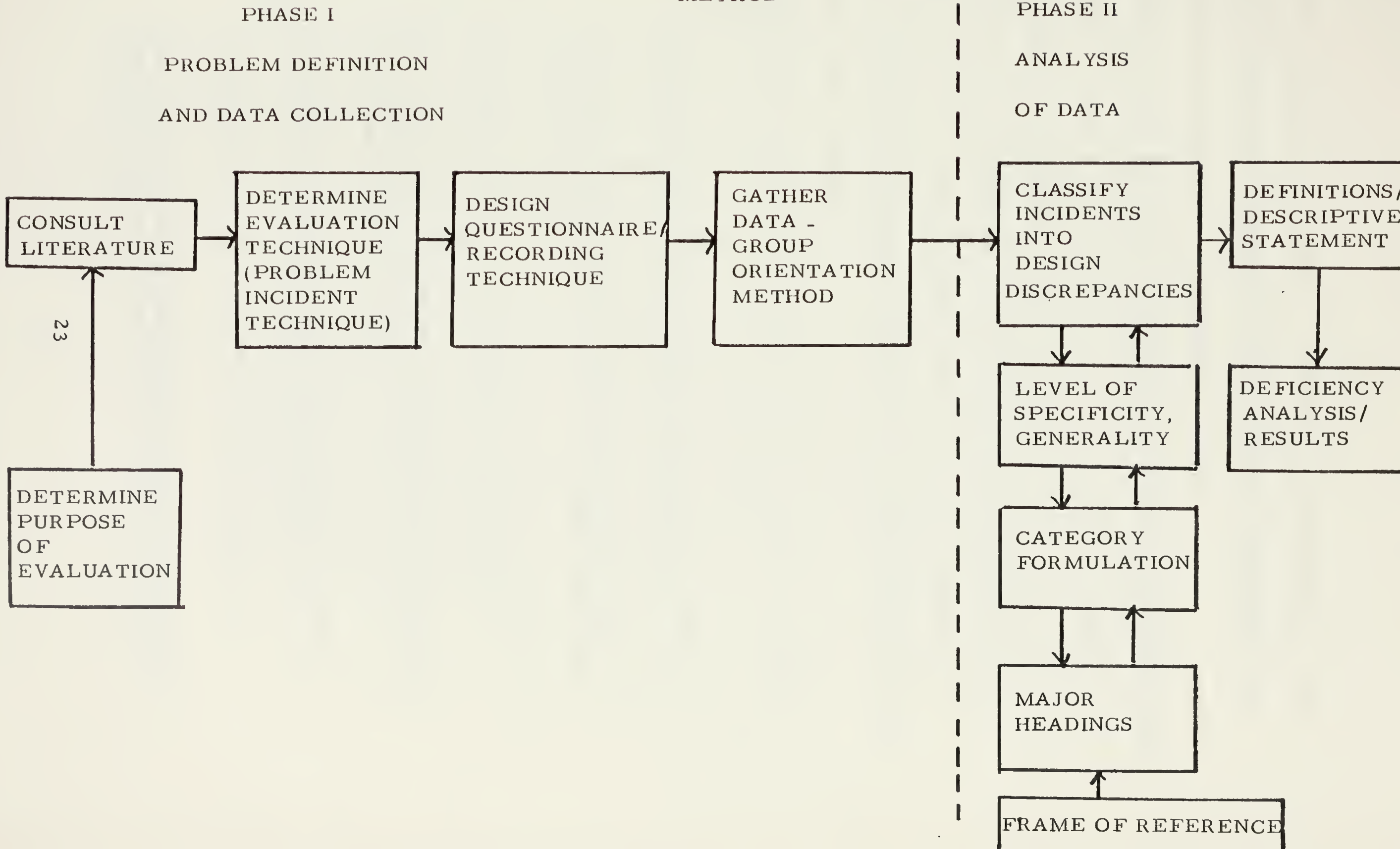
the feasibility and value of the Problem Incident Technique in order to justify its projection to the squadron level (as a fleet-wide source of data). To this end the safety school provides in a sense a "worst case" source of information. After all if the more experienced element of the fleet identifies discrepancies they certainly cannot be excused as solely pilot inexperience. Such errors must be regarded as relevant and worthy of further study.

B. METHOD

A method of exploration was sought which could uncover what things operators found troublesome with their equipment and could also provide a vehicle for further hypothesis formulation. Thus a method was needed to facilitate the collection and processing of this type of information. The basic steps involved are presented in Figure 3 and provide a guide for this entire study. Phase II, the analysis section, is closely aligned to the Critical Incident Technique (Flanagan, 1962), which was later refined by Meister and Rabideau (1965) into the Problem Incident Reporting Technique.

Because of the cost in time and personnel, alternatives to individual interviews were sought for data collection. As noted earlier Vasilas et al (1953) suggested that a group orientation method was highly effective in facilitating the collection of reported incidents. The method uses an interviewer to instruct small groups of airmen in both the nature of the procedure and the value of such a study. The respondents then

FIGURE 3
METHOD



describe incidents from memory. This retains the advantages of the individual interview in regard to personal contact, explanation, and availability of the interviewer to answer questions.

Daniels (1976) developed a two page questionnaire and demonstrated its potential towards obtaining useful results in a safety school environment. Appendix A contains completed samples of the report forms which are representative of the anecdotes elicited during this study. The initial presentation which was read verbatim to each group prior to report completion is reprinted in Appendix B. Forty-five minutes was alloted for each evolution.

The following guides to development were adhered to in order to develop adequate means of collection and recording:

1. The introductory remarks were standardized in order to maintain continuity across safety school classes.

2. The report form stresses anonymity in order to avoid inadequate responses due to fear of reprisal, evaluation, or social pressures.

3. The initial remarks were tailored to create a general atmosphere of cooperation with the respondents.

4. The recording technique was engineered to be simple and thus easily understood by all participants; it also required a minimum of time and skill.

5. Provision was made for eliciting the necessary control information - aircraft model, crew position, etc.

6. The record form was amenable to easy handling and sorting.

7. The evaluator was not searching for particular problems; thus there was no attempt to direct questions towards any specific area.

C. ANALYSIS OF DATA

The purpose of the data analysis stage is to summarize and describe the reported incidents in an efficient manner so that they may be applied to problems of design. The aim is to increase the utility of the information while sacrificing as little as possible of its comprehensiveness, specificity, and validity.

The raw material for the analysis consisted of a descriptive report for each incident elicited. It should be recognized that each report is a unique anecdote describing a unique event. Thus each incident reported was transcribed, along with all control data, onto three by five cards and considered as one data point.

The procedures used at this stage were proposed by Flanagan (1962); the general steps involved in the process are reproduced in Figure 4. There are three primary areas that are of critical importance which will be discussed in detail. However it is worthwhile to keep in mind some observations taken from a study of accidents by Thorndike (1951):

> "Note that the issue with respect to a particular way of analyzing accidents is not whether it is right or wrong. Any way of analyzing and any set of categories is 'right' as long as the categories are non-overlapping and are collectively inclusive. The fundamental issue is whether the system of analysis is the most useful one, that is, whether it can best serve as the basis for analyses which will answer practical questions and suggest courses of action which are likely to change things for the better."

a. Frame of reference

Any system orientation will be based upon the judgment of the individuals performing the analysis; but, in general, the primary

Figure 4.

GUIDE FOR ANALYSIS OF REPORTED DESIGN DISCREPANCIES

1. Select general frame of reference.

2. Sort a sample of incidents into a few piles in accordance with the frame of reference selected.

3. Formulate tentative headings for major areas.

4. Sort additional incidents into these major areas; set up new sub-categories as they appear necessary. During this process time will be saved if all incidents which are so similar that they will remain together regardless of changes in category definitions are clipped together and treated as one unit.

5. After a substantial portion of the incidents have been classified, prepare tentative definitions for major headings and generalized statements for each of the main categories of requirements.

6. Make a tentative selection of the level of specificity-generality to be used in reporting the definition.

7. Redefine major areas and categories as necessary while incidents are being classified.

8. After all incidents have been classified, review definitions and revise where necessary.

9. Record the classification of each incident on the back of the card.

10. Have an independent check made on the classification of all incidents.

consideration should be the uses to be made of the data. It was determined that the primary thrust of this study was to be an exploration into the problems exhibited across aircraft types and communities. The purpose is to demonstrate that common problems exist and that they can be analyzed. It was desired to determine a design deficiency stratification that would encompass each and every data point available; hypotheses could then be generated and provide inspiration for recommending further work.

b. Category formulation

The general process by which the data was evaluated and stratified involves category formulation. This portion of the procedure is more subjective than objective, but, in general, the process involves grouping similar incidents under major headings, then into categories, deriving subgroups, and finally formulating descriptive statements where appropriate.

The initial step dealt with the derivation of a trial classification system. Reports published on studies similar to the current effort (see history) plus the author's experience as a fleet aviator, provided the initial insight, experience and judgment for filing a small sample of incidents into areas consistent with the frame of reference. These data aggregations then became the initial major headings and were loosely defined. Additional incidents were then classified under major headings into subheadings called categories. This step was iterative with regard

to the trial and revision of these categories; in fact, the classification system as a whole was subjected to a constant evolution throughout the entire process. The goal sought was a workable classification system which encompassed all incidents and had a non-overlapping and distinctly defined format.

A need for subgroups within the categories soon became apparent. These were developed on an entirely inductive basis; they consisted of groups of incidents describing very nearly the same design discrepancies.

Each incident was carefully read and re-read before assigning it to the system. If an incident could not be readily assigned, a revision in the stratification scheme was made by broadening existing headings, categories, and/or subgroups, or by adding new ones as appropriate.

c. Level of specificity/generality

This area concerned the specificity achieved in particular incidents versus the simplicity of a relatively smaller but more useful number of headings. Several considerations were adhered to at this level:

1. A clear cut and logical organization was sought which could be presented in standard outline form.

2. Titles were sought for all headings, categories, and subgroups which could convey meaning in themselves. Nonetheless, definitions and descriptive statements were still provided.

3, The stratification scheme chosen was that deemed maximally useful in highlighting design problem areas, yet which was still significant at each level in terms of frequency of occurrence.

4. A descriptive statement was written for each group of duplicate incidents or for each single incident representing a distinctly different design discrepancy.

5. Descriptive statements were written in terms sufficiently general to cover basic similarities yet specific enough to delineate specific problem areas.

After the initial system evolution it became obvious that the number of categories involved resulted in an unwieldy system. A reduction was made by combining similar subgroups and writing new descriptive statements. The essence of the subgroups was preserved but some specific detail (common to some but not all of the incidents) was lost.

After all classification was completed and the level of specificity/generality deemed satisfactory, the definitions and descriptive statements were closely re-examined in terms of the actual incidents as now classified. Alterations were made where required.

VI. RESULTS

Results were elicited from five separate safety school classes during the period October, 1975, to February, 1976. A total of 137 aviators were questioned resulting in 286 reported design discrepancies. The procedure yielded an average of 2.09 incidents per respondent. The results suggest that fleet aviators have something to say about design deficiencies. Fleet experience was indicated by averages of 1816 total flight hours per respondent, and also 201 flight hours/respondent in the aircraft reported on during the past six months.

The sample as a whole contained data points covering twenty-six different Navy aircraft, an indication of the breadth of the information across communities. Table 1 presents the relevant control data in tabular form broken down by individual aircraft and respondent status (Pilot, NFO). The table reveals some notable influences which occur when using safety school data as a microcosm for the fleet. Pilots significantly outnumber NFO's by a 8 to 1 margin, a significantly greater ratio than might be expected. Only the F-4 community seems to have adequate NFO representation. It was also noted that 49% of the data was received from the P-3, F-4, A-6, and A-4 communities. In fact, 72.8% came from the fighter, attack, and ASW communities. However, these are also clearly the main components of the present day force structure.

TABLE I SUBJECT DATA

	# SUBJECTS			# INCIDENTS REPORTED			% TOTAL INCIDENTS REPORTED
AIRCRAFT TYPE	PIL	NFO	TOTAL	PIL	NFO	TOTAL	
ATTACK							
A-4	14	-	14	34	-	34	11.9
RA-5	3	2	5	9	6	15	5.2
A-6	13	2	15	29	3	32	11.2
A-7	7	-	7	20	-	20	7
A-3	1	-	1	1	-	1	.35
Total Attack			42			102	35.65
FIGHTER							
F-4	7	8	15	17	18	35	12.25
F-8	3	-	3	6	-	6	2.1
F-14	2	2	4	3	5	8	2.8
Total Fighter			22			49	17.15
PATROL/ASW							
S-2	10	-	10	12	-	12	4.2
S-3	2	-	2	5	-	5	1.7
P-3	20	1	21	37	3	40	14.
Total ASW			33			57	20
AEW							
E-2	8	0	8	18	4	22	7.7
OV-10	2	-	2	3	-	3	1
Total AEW			10			25	8.7

TABLE I SUBJECT DATA - continued

	# SUBJECTS			# INCIDENTS REPORTED			% TOTAL INCIDENTS REPORTED
AIRCRAFT TYPE	PIL	NFO	TOTAL	PIL	NFO	TOTAL	
TRAINER							
T-2	3	-	3	6	-	6	2.1
T-28	4	-	4	6	-	6	2.1
T-29	1	-	1	2	-	2	.7
T-39	1	-	1	1	-	1	.35
Total Trainer			9			15	5.25
TRANSPORT							
C-9	1	-	1	1	-	1	.35
C-130	5	-	5	9	-	9	3.1
C-1	1	-	1	2	-	2	.7
C-117	1	-	1	1	-	1	.35
C-121	1	-	1	1	-	1	.35
Total Transport			9			14	4.85
HELICOPTER							
UH-1	3	-	3	4	-	4	1.4
H-3	5	-	5	12	-	12	4.2
H-46	3	-	3	5	-	5	1.8
H-53	1	-	1	3	-	3	1
Total Helo			12			24	8.4
TOTALS	122	15	137	247	39	286	100

Table II presents the general headings and categories developed through application of the Problem Incident Reporting Technique. Statistics included are total discrepancies per heading, total per category, and frequency of report per heading. The complete analysis is presented in Table III. It consists of a systematically collected set of 31 subgroups, 10 categories, and 5 headings elucidating those design problems viewed as significant by fleet operators. Each subgroup is quantified by number of discrepancies and frequency of report. Descriptive statements and definitions are provided where appropriate.

In terms of frequency or relative proportions, the grouping under the second general heading, Aircraft Cockpit Layout Errors, seems most important. One hundred and forty-seven documented incidents, representing 51.4% of all reported design discrepancies, fall under this heading. An examination of the subgroups under the three categories which evolved (control/display location, control/display geometry, and workspace area) reveals problem areas which might not be anticipated by an engineer lacking aviation experience and working with a stationary mockup. Twenty-five location errors which prohibit an effective visual instrument scan were reported. Eighteen discrepancies revealed that certain controls or displays were difficult for aviators to use not because of design, but because they were hidden behind other aircraft fixtures. There were 28 reports that aviators could not reach or activate a control when properly seated in the aircraft. In addition 53 other discrepancies were reported in the workspace area, an aviator's "office" -

TABLE II

BREAKDOWN OF INCIDENTS BY
MAJOR HEADING AND CATEGORY

		CATEGORY INCIDENTS	HEADING TOTAL	%
I.	EQUIPMENT DESIGN		69	24.13
	A. Control	39		
	B. Display	30		
II.	AIRCRAFT COCKPIT LAYOUT ERRORS		147	51.4
	A. Control and Display Location	60		
	B. Control and Display Geometry	34		
	C. Workspace Area	53		
III.	VISION		23	8.04
	A. Internal	15		
	B. External	8		
IV.	ENVIRONMENT		27	9.44
	A. Environmental Control	13		
	B. Life Support	14		
V.	SAFETY		20	6.99
	A. Inadequate Safety Factors	20		
	TOTALS	286	286	100

TABLE III

ANALYSIS OF 286 OPERATOR GENERATED NAVAL AIRCRAFT DESIGN DISCREPANCIES

	NO. OF INCIDENTS	%
I. EQUIPMENT DESIGN		
A. Control		
1. Distinction Errors: Errors resulting from inability to distinguish among switches in close proximity and/or confusion among switches similar in size and shape.	15	5.2
2. Adjustment Errors: Operating control requires excessive visual attention because of "lack of feel" or because of excessive physical effort in actuating.	6	2.1
3. Excessive Positive Actuation: Control requires a significant time period of actuation for operation.	4	1.4
4. Reversal Errors: Control must be moved in a direction opposite to that necessary to produce desired result.	3	1.0
5. Unintentional Activation: Control positioned/designed such that danger exists of inadvertently operating it without an awareness of doing so.	11	3.8
B. Display		
1. Parallex: Difficulty in reading instrument as required because of angle from which it is viewed.	11	3.8
2. Legibility: Errors which result from difficulty in seeing the desired information distinctly enough to interpret indication properly.	6	2.1

TABLE III - continued

	NO. OF INCIDENTS	%
3. Interpretation: Instrument indication subject to misinterpretation with the result that subsequent actions may aggravate vice correct undesirable condition	4	1.4
4. Unreliability From Poor Construction: Display does not attract attention and/or not utilized due to poor design.	9	3.2
II. AIRCRAFT COCKPIT LAYOUT ERRORS		
A. Control/Display Location		
1. Vertigo Inducing Location: Instrument requires visual check causing a distraction which, under certain circumstances, may result in a contradiction between the information received by a pilot through his vestibular (or labyrinthine) sense and through his visual sense.	17	6
2. Location Prohibits Effective Scan: Control or display placed such that an effective visual instrument scan must be broken to activate/check.	25	8.8
3. Controls, Displays Hidden Behind Other Aircraft Fixtures	18	6.3
B. Control, Display Geometry: Problems associated with dimensional arrangement of crew station.		
1. Inadequate Placement, Displays: Dimensional layout of cockpit makes display difficult to see.	6	2.1
2. Inadequate Placement, Controls: Dimensional layout of cockpit makes control difficult to reach/activate when pilot properly seated and harnessed.	28	9.8

TABLE III - continued

	NO. OF INCIDENTS	%
C. Workspace Area		
1. Operation and Maintenance Consoles.		
a. Insufficient Instrumentation: Operator does not have necessary instrumentation for proper performance of his duties.	17	6
b. Lack of Standardization: Cockpit instrumentation not standardized across variations of the same aircraft type.	5	1.75
2. Inadequate Storage: More stowage space required for publications and emergency equipment-items which could become missiles in a ditching/heavy turbulence situation.	3	1.0
3. Lack of Well Lit, Well Situated Approach Plate Holder.	11	3.9
4. Ingress/Egress: Problems associated with the crewman's ability to exit or enter the crew station both normally and during an emergency.	13	4.6
5. Comfort/Mobility: Problems associated with crewman's comfort and his ability to move around in the crew station in order to perform his duties.	4	1.4
III. VISION		
A. Internal Vision: Problems which interfere with a crewman's ability to acquire internal cues (i.e., lighting too dim, too difficult to see instrument indication in sunlight).	15	5.3
B. External Vision: Problems which interfere with crewman's ability to acquire external cues (i.e., night display lighting reflects off canopy).	8	2.8

TABLE III - continued

	NO. OF INCIDENTS	%
IV. ENVIRONMENT		
A. Environmental Control: Problems associated with environmental factors which have a direct behavior on operator performance.		
1. Temperature/Ventilation	5	1.75
2. Noise/Vibration	8	2.8
B. Life Support: Problems associated with an aviator's personal equipment, survival equipment, etc.		
1. Oxygen/Smoke mask	5	1.75
2. Protective clothing	3	1.0
3. Restraint gear	5	1.75
4. Relief tube	1	.035
V. SAFETY		
A. Inadequate Safety Factors: Operator identified discrepancies which could potentially evolve into conditions not conducive to good safety practice.		
1. Air canopy problems	7	2.5
2. Training/NATOPS procedures, lack of	3	1.1
3. Ejection seat/seat pan	4	1.4
4. Inadequate/insufficient safety features (i.e., equipment hard to reach in an emergency, lack of weather radar, lack of safety checks).	6	2.1

all problems that could have been avoided by more knowledgeable direction in the design phase. Clearly, design engineers have problems in conceptualizing the plight of an aviator in an actual operational environment.

Judging from frequencies the design of the control or display itself is next in importance. Sixty-nine such incidents were analyzed in Table III. Particularly noteworthy was the similarity between sub-groups which evolved from this report and those which Fitts and Jones (1947a, 1947b) constructed from pilot error analyses of aircraft control operation and instrument interpretation. The twenty-nine year time span between the reports indicates the necessity for the transmittal of this type of information to designers. It also suggests the absence of corporate memory in Naval Aviation.

The discrepancies defined under the remaining three major headings comprised only 24.47% of the total incidents. Yet it must be remembered that only one incident, if well documented, is of significant importance.

Any factors which interrupt an aviator's visual perspective, either internal or external to his craft, can have a degrading effect on total system performance. There were 15 reported cases of excessively dim lighting at night, instruments that were unreadable in sunlight, and other problems which interfered with an aviator's ability to acquire internal cues. Nine incidents (such as night canopy relfection from display lighting) resulted from external vision interrupts. Here again are discrepancies that would be difficult to forecast from a mockup or simulator.

Also difficult to predict, but within the realm of human factors, are the environmental control and life support design problems elicited. Problems involving temperature, ventilation, noise, vibration, and life support equipment all affect a crewman's perception of his environment and influence his performance.

The final heading was a loosely defined grouping termed Safety. These were, in fact, discrepancies which operators felt could result in conditions not conducive to good safety practices. Some, such as lack of training/NATOPS procedures, might be viewed as foreign to the design process. Yet it is at this early stage where initial iterations for such procedures might be formulated.

Table IV presents a breakdown of the classification system versus the four aircraft with the largest sample sizes - P-3, A-4, F-4, A-6 - measured in terms of frequency of responses per given aircraft. The table gives an idea of the dispersion of individual aircraft responses among the various headings and categories. These models have all undergone various modifications; the A-4 and F-4 are in the twilight of their careers. It is clear that the classification scheme represents design discrepancies which affect all individual aircraft and yet which have gone uncorrected by design engineers over a substantial period of aircraft evolution. If such problems have not been pinpointed in the past, there is little reason to expect them to be accounted for in new aircraft.

TABLE IV

DISCREPANCY ANALYSIS VERSUS FOUR AIRCRAFT TYPES

	% P-3	% A-4	% F-4	% A-6
I. EQUIPMENT DESIGN				
A. Control	2.5	17.6	11.4	6.2
B. Display	15	3	2.9	18.8
II. A/C CONTROL LAYOUT ERRORS				
A. Control/Display Location	10	26.4	17.1	25
B. Control/Display Geometry	5	20.6	17.1	15.6
C. Workspace Area	40	14.6	14.3	18.8
III. VISION				
A. Internal	5	3	2.9	0
B. External	0	3	2.9	12.5
IV. ENVIRONMENT				
A. Environmental Control	7.5	3	8.6	0
B. Life Support	12.5	5.8	5.7	3.1
V. SAFETY				
A. Inadequate Safety Factors	2.5	3	17.1	0
	100%	100%	100%	100%

It can also now be said that two types of requirements arise when discussing design problems:

1. Those inspired by specific aircraft deficiencies.

2. Those which are based upon a need by all aircraft.

The current effort presents a stratification that can serve as the foundation for study of either requirement as the descriptive statements written for this analysis are generally applicable. A more specific and detailed analysis tailored towards either of the above directions would lead to more critical discrepancy areas for which specific remedial procedures might be devised. This relates directly to the question of, "How many incidents should be collected?" Flanagan (1962) suggests a criteria that would lead to a much larger sample than the present one; namely, adequate sampling is achieved when the addition of 100 incidents results in only two or three new discrepancies. This type of very detailed work could spell out specific trouble spots upon which attention could be focused for the purpose of understanding and diagnosis.

VII. CONCLUSIONS

Although the level of specificity/generality did not allow specific identification of error causing equipment, the results do provide a view of the problems which hinder operator performance. The derived design deficiency structure demonstrated that an identifiable body of common cause factors exists across a large number of different Naval aircraft. The constant nature of the problem suggests that the causes are rooted in the aviation system itself and that research should be directed towards conceptual deficiencies in the design of air weapons systems in general.

Previous discussion established a link between equipment design as a system element and the operator in terms of an error causing overload conditions. Each of the design problems identified in this paper can induce such a state providing it occurs at a critical time during the mission. It is not the deficiency area per se that is important, but rather the interactive characteristics an area has with the system as a whole. As a result equipment may seem perfectly adequate to the human factors specialist when evaluated alone, while actually being inadequate when interacting with other system elements (including the operator) in the complex operational environment.

Research needs to consider not only specific problems of equipment design, but to study a system in terms of the interaction of its elements.

System breakdowns, as well as individual equipment inadequacies, directly affect mission performance. Thus the Navy needs a system development program which includes consideration of total system operation (rather than merely operability) from the earliest of design stages. A start has been made in this direction by the approach presented in this study; deficiencies as deduced by the presented method reveal a unique view of problems as experienced in a systems context.

With regard to the presented collection, classification, and analysis of the deficiency data, the author concluded that:

1. Fleet aviators do feel that man-machine interface problems exist which hamper their mission performance.
2. Aviators are able and willing to articulate and document these problems.
3. The Problem Incident Reporting Technique contributes to an effective method for systematically collecting, analyzing, classifying, and describing the reported problem incidents.
4. The continuation of the same discrepancy problem areas across generations of Naval aircraft and their continued inclusion in design suggests that operational problems do exist which cannot be anticipated by the design engineer using current techniques.
5. The presented method can identify these operational problem areas which have been historically ignored.

6. The utilization of such information in the design stage can result in:

   a. improved performance in weapon systems cockpit and the man-machine interface design,

   b. improved manpower utilization and performance,

   c. fewer aircraft mishaps and an alleviation of mission degradation from equipment misuse,

   d. improved user acceptance,

   e. reduced training cost as aviators no longer must learn methods devised to circumvent design problems.

7. Thus, a system has been devised for the total analysis of reported design discrepancies which yields:

   a. a new source of specific and detailed data which provides considerably more information on important design problems than those currently available.

   b. a system for the classification and analysis of the data in such a way as to facilitate remedial action.

VIII. RECOMMENDATIONS

This project represents the second iteration in developing a program for obtaining and utilizing design discrepancy data. The study used a questionnaire developed by Daniels (1976); however, the experience accumulated in the course of this work indicates that valuable information was left undetected. Chapanis (1959) suggests that a project of this nature should elicit data that suggests cures. And, in fact, many aviators offered plausible solutions to the design problems which they described. In addition it would have been advisable to ask more specific questions in order to determine the phase of the mission which was affected, what the aviator did, and in what ways the problem degraded the flight. In this way an idea of the criticality in terms of mission performance could be devised. It is suggested that this be dealt with in a series of follow up projects; however, a solid starting point would be a record form developed by the American Institute for Research and used by Vasilas et al (1953) in a study of near accidents (see Appendix C).

Eventually the study should be expanded to collecting design discrepancy data from all crew members on a fleet-wide basis. Practical procedures and channels must be devised for routing reports to squadrons, for application within squadrons, and for routing back to the collection agencies. In addition channels for effecting the corrective

actions dictated by the analysis must be established. The facilities of the Naval Postgraduate School, the Naval Safety School, and the Naval Air Development Center should be explored with respect to establishing such procedures.

It must be recognized that the data used in such a study as this is subjective. It is recommended that the design discrepancies which result from such data be substantiated with other observable data and documented reports. Aircraft inspections could be conducted and safety data screened for such validation purposes. The process when bolstered by additional information can only gain in credibility.

Finally it is recommended that the resultant findings be forwarded to the human engineer with the recommendation that the solutions be included in the design specification. Meister and Farr (1966) in a study of the utilization of human factors by designers suggest:

> "The primary means of ensuring the inclusion of Human Factors in design is through the design specification .... We recommend that when consideration of Human Factors is desired, the customer insert strongly worded statements in the design specification ....."

If an effective communications link is established from the squadron through the collecting agency to the contractor, perhaps the design problems that have plagued Naval aviators through generations can be mitigated.

APPENDIX A

COCKPIT HUMAN FACTORS DEFICIENCY QUESTIONNAIRE

SECTION I - RESPONDENT DATA

85 Date 19 Jan.

Pilot NFO (check one)

Total Flight time 2150

Aircraft flown most in last 6 months. Type A-4M (ECP 1120) Hours 200

Do you think the data we are trying to get is available elsewhere? Yes No
If yes, where? ______

SECTION II - IDENTIFICATION OR DESCRIPTION OF DEFICIENCY

	ITEM 1	ITEM 2	ITEM 3	ITEM 4
Type(s) of aircraft involved	A-4M	A-4M	A-4M	A-4M
Name of deficient item	ARC-159 (placement of)	nosewheel steering button	fuel trans light	AOA ind.
Component ID (if known)		(dual function)		
Manufacturer (if known)		Douglas Elliot HUD		Douglas

Was this item/situation standard? Yes No

	ITEM 1	ITEM 2	ITEM 3	ITEM 4
i. e. Did it occur on all aircraft in type?	yes	yes	yes	yes

If NO, describe below

SECTION III - BRIEFLY DESCRIBE THE SITUATION AND ITS POTENTIAL EFFECTS

Item 1

"In the new A-4M with ECP 1120 (HUD), the cockpit lay-out has improved but, there are still some environmental problems. The ARC 159 a new UHF radio is the best I have ever had the opportunity to use. But, it is still located down on the console; it was moved from the right console to the left which was an improvement - facilitating keeping right hand on stick. However, it is just about abeam one's left upper thigh. When making a channel change especially night, IFR, formation it is necessary to look down and to the left to read the new frequency. This is dangerous and impractical. Mount the radio on the left upper instrument panel or have a readout from the radio displayed in that position. The OV-10 is a good example of radio placement. It makes it much more comfortable and less vertigo inducing to switch frequencies while maintaining good look-out doctrine."

Item 2.
"The nose wheel steering button has a dual function in A/C with the (HUD). During weapons delivery if the master armament switch is cycled on-off, as in coming off a run, the pipper and bomb actuation line disappears. In order to regain this presentation the pilot must depress the nosewheel steering button. No one knows why this feature was even incorporated to begin with. The presentation does not impair one's view and as a result of depressing the nosewheel steering button many pilots have already inadvertently depressed the bomb pickle button dropping ordnance anywhere and everywhere. I suggest removing this feature of the nosewheel steering (dual purpose) and merely leaving the pipper and bomb actuation line always displayed. All pilots in my present squadron concur - it's a ridiculous feature."

Item 3.
"There is no longer a fuel transfer light in the new A-4M displayed on the enunciator panel. The NATOPS makes reference to it still being there but it is not. A change has already been submitted to the NATOPS manual. However, the pilots would like to have the light back. There is presently no way to discriminate between a stuck float valve and a fuel transfer failure. They are both indicated by a drop in fuel quant. to approx. 1100 lbs. followed by a low fuel light."

Item 4.
"The AOA indicator is in a poor position for the pilot to see when seat is in upper position for landing. Raise the whole indicator for better landing A/S monitoring."

APPENDIX A - continued

COCKPIT HUMAN FACTORS DEFICIENCY QUESTIONNAIRE

SECTION I - RESPONDENT DATA

#49 Date 10 Nov 75

Pilot NFO (check one)

Total Flight time 4500

Aircraft flown most in last 6 months. Type P-3C Hours 30

Do you think the data we are trying to get is available elsewhere?
Yes No . If yes, where? ______________________________

SECTION II - IDENTIFICATION OR DESCRIPTION OF DEFICIENCY

OF DEFICIENCY	ITEM 1	ITEM 2	ITEM 3
Type(s) of aircraft involved	P-3C	P-3C	P-3C
Name of deficient item	Approach plate holder	flight director indicator	vertical speed indicator
Component ID (if known)			
Manufacturer (if known)			
Was this item/situation standard? Yes No i.e. Did it occur on all aircraft in type? If NO, describe below	yes	yes	yes

SECTION III - BRIEFLY DESCRIBE THE SITUATION AND ITS POTENTIAL EFFECTS

Item 1

"In the P3C aircraft there is no holder provided for the approach plate/departure plate book. Many 'made do' adaptations have been designed and used by various individuals. These jury rigs usually involve clipping a sheet aluminum plate somewhere under the glare-shield or at the edge. Most of these locations cause certain instrument/indicators to be hidden from the pilots scan. Also none of these locally manufactured solutions are lighted causing night approaches to be less safe by the pilot/co-pilots moving the approach plate to a light source."

Item 2

"The Flight Director Indicator (FDI) in the P3C provides the primary horizon reference under IFR conditions. The 'pipper' is non-adjustable by the pilot. Depending on the height -of-eye of the viewer it will indicate a climb or descent when in fact the aircraft is straight and level. It causes instrument fixation and disorientation during the instrument flight. Without an operational AFCS it is extremely difficult to fly straight and level."

Item 3

"The pilots VSI is too small for its position on the instrument panel. It should either be the larger type gauge or be repositioned. (Note: They might have taken the c/p VSI out of the P3C. I'm not sure as I haven't had a chance to fly in the rt. seat.)"

APPENDIX B

INSTRUCTIONS FOR FILLING OUT THE COCKPIT HUMAN FACTORS DEFICIENCY QUESTIONNAIRE

There is presently no large data base, from the pilot's point of view, for problems that the pilot faces caused by the cockpit and its equipment. It may be too late or expensive to change the specific items or address specific problems that relate to known deficiencies today. However, the hope is that a data base made up of such problems, statistically relevant and properly presented in the DESIGN stage of tomorrow's cockpits may save us from having these same or similar problems on our next tour.

The number and date are for statistical purposes only and have been filled out by the instructor. Since the questionnaires have been randomly distributed, you may anonymously speak your mind.

Please operate independently, since if all the P-3 drivers come up with the same item it will tell us one thing (which we don't want). If you all come up with a different item, that will tell us something also.

It is anticipated that 95% of the items will be UNCLASS, however, if the item you wish to relate is classified, please so mark your questionnaire and personally let me know so that the special markings and handling may be complied with.

Now specifically, think back on your last flight experience and remember some cockpit piece of equipment, murphy, or design feature that was a problem (couldn't reach, see, feel, hear, actuate, etc.) Almost any specific item that caused some difficulty, lack of coordination, hazard, noise, temperature, etc. will be helpful. If you have two or three, so much the better. Space is provided for three items.

Everybody got an item? If not, keep thinking back on flights until you get at least one. OK, carry on!

APPENDIX C

HAZARDOUS INCIDENT REPORT

(1) Base: Acft type: Date:

check ( ) or complete the following applicable data:

DAWN DAY DUSK NIGHT Clearance: VFR IFR LOCAL

PHASE OF FLIGHT:

TAXIING TAKEOFF CLIMB CRUISE DESCENT APPROACH

LANDING OTHER ___________ TYPE OF MISSION: ___________

NARRATIVE DESCRIPTION OF INCIDENT

(2) Give enough details so that the story will be clear. Use other side if more space is needed.

A. Describe what led to the hazardous incident ___________

B. What did you do? ___________

C. What was the immediate result? ___________

D. What would be the best way of handling the situation if it happened again? ___________

E. How could such a hazard be eliminated or avoided? ___________

------

(3) Check your crew position

Pilot Co-pilot Bombadier Navigator Observer

Radar operator Engineer Gunner Other ___________

Developed by
The American Institute for Research

BIBLIOGRAPHY

Atkins, T. W. Aircrew station geometry in selected USAF aircraft. USAF: AFELL-TR-69-73, Air Force Flight Dynamics Laboratory, November, 1969.

Atkins, E.R., McClung, W., and McClendon, R.G. Crew station geometry and equipment evaluation for USAF aircraft. Dallas: AFFDL-TR-69-73, LTV Aerospace Corporation, November, 1969.

Chapanis, Alphonse. Research Techniques in Human Engineering. Baltimore: the John Hopkins Press, 1959.

Daniels, G. F. Pilot reported Human Factor cockpit discrepancies in Naval aircraft. Master's thesis, Naval Postgraduate School, Monterey, California, 1976.

Fitts, P.M., and Jones, R.E. Analysis of factors contributing to 460 "pilot error" experiences in operating aircraft controls. USAF: Memorandum report TSEAA-694-12, Aero Medical Laboratory, Air Material Command, Wright-Patterson AFB, Ohio, 1 July, 1947 (A).

Fitts, P.M., and Jones, R.E. Psychological aspects of instrument display, 1. Analysis of 270 "pilot error" experiences in reading and interpreting aircraft instruments. USAF: Memorandum report TSEAA-694-12A, Aero Medical Laboratory, Air Material Command, Wright-Patterson AFB, Ohio, 1 July, 1947 (B).

Flanagan, J.C. Measuring Human Performance. University of Pittsburgh and American Institute of Research, 1962.

Gagne, Robert M. (Ed.) Psychological Principles in System Development. New York: Holt, Rinehart and Winston, 1962.

Johnson, S.L., and Roscoe, S.N. What moves, the airplane or the world? Human Factors, 1972, 14(2), 107-129.

Korchin, B., and Patterson, J.N. Evaluation of Naval flight safety media. NRC Committee on Aviation Psychology report no. 1, Division of Aviation Medicine, Bureau of Medicine and Surgery, March, 1949.

Meister, David. Human Factors: Theory and Practice. New York: Wiley-Interscience, 1971.

Meister, D., and Farr, D. The utilization of human factors information by designers. Canoga Park, California: The Bunker-Ramo Corporation, Contract NONR-4974-00 amendment no. 1, September, 1966.

Meister, D., and Rabideau, G. F. Human Factors Evaluation in System Development. New York: John Wiley & Sons, 1965.

Meister, D., and Sullivan, D. J. A further study of the use of human factors information by designers. Canoga Park, California: The Bunker-Ramo Corporation, Contract NONR-4974-00 amendment no. 2, March 1967.

Rabideau, Gerald F. Human factors data gathering in operational systems. Proceedings of the Human Factors Testing Conference 1-2 October, 1968. J. P. Kincaid and K. W. Potempa (Eds.) USAF:AFHRL-TR-69-6, Air Force Human Resources Laboratory, October, 1969.

Rabideau, G. F., and Ritchie, M. L. Human engineering critical incident survey of Air Force tactical air operations in Vietnam. USAF: Contract F33615-67-C-1820, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, August, 1968.

Ricketson, Darwin S. Pilot error as a cause of Army helicopter accidents. US Army: United States Army Agency for Aviation Safety paper presented at Office of the Chief of Research and Development conference on aircrew performance in Army aviation, Fort Rucker, Alabama, November 1973.

Ricketson, D.S., Kennamore, J.R., and Callen, J.R. Pilot errors aren't all pilot. US Army: US Army Agency for Aviation Safety, Fort Rucker, Alabama, May, 1975.

Ricketson, D.S., and others. Incidence, cost and factor analysis of pilot-error accidents in U.S. Army aviation. US Army: United States Army Agency for Aviation Safety paper for presentation at meeting of advisory group for Aerospace Research and Development North Atlantic Treaty Organization, Soesterberg, Netherlands, September, 1973.

Shapiro, A. J., and others. Human engineering testing and malfunction data collection in weapon system test programs. USAF: WADD-TR-60-36, Wright-Patterson AFB, Ohio, February, 1960.

Thorndike, R.L. The human factor in accidents with special reference to aircraft accidents. USAF: ATI-102123, USAF School of Aviation Medicine, Randolph Field, Texas, February, 1951.

Weislogel, R.L. Detection of error producing designs. Human Factors Methods for System Design. John D. Folley (Ed.) Office of Naval Research: AIR-290-60-FR-225, The American Institute for Research, 1960.

Wherry, R.J. Air Weapon System Development Program. Unpublished manuscript, available from the Human Factors Engineering Division, Naval Air Development Center, Warminster, Pennsylvania, 1975.

Woodson, W.E., and Conover, D.W. Human Engineering Guide for Equipment Designers. Berkeley: University of California Press, 1966.

Van Cott, H.P., and Kincaide, R.G. (Eds.) Human Engineering Guide to Equipment Design. (Revised edition) Washington, D.C.: U.S. Government Printing Office, 1972.

Vasilas, J.N., and others. Human factors in near accidents. USAF: Project number 21-1207-0001 report number 1, USAF School of Aviation Medicine, Randolph Field, Texas, June, 1953.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
4.	CDR L. E. Waldeisen, Code 55Wd Naval Postgraduate School Monterey, California 93940	1
5.	Asst. Professor D. E. Neil, Code 55Ni Naval Postgraduate School Monterey, California 93940	2
6.	CDR A. C. Yelle, USN VP Prog Dir Code 50P3 Naval Air Development Center Warminster, Pa. 18974	1
7.	Mr. W. A. Leyland Code 5420 Naval Air Development Center Warminster, Pa. 18974	1
8.	LT Frederick G. Schobert, USN Detachment Agana, Patrol Wing One Box 66, U. S. Naval Air Station FPO San Francisco 96637	1

168872

Thesis
S33798 Schobert
c.1 An investigation of
user generated cockpit
discrepancies in naval
aircraft.